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(71) Applicant: Hewlett-Packard Company
3000 Hanover Street
Palo Alto California 94304(US)

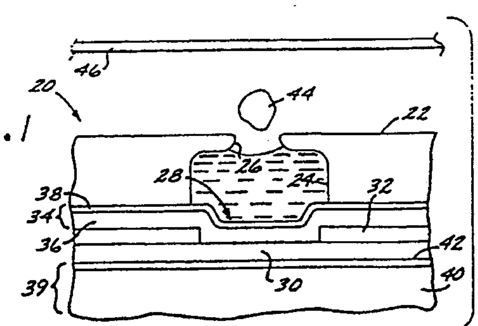
(72) Inventor: Nigro, Stephen Jame
11392 Grassy Trail Drive
San Diego CA.92127(US)
Inventor: Johnson, David Alan
2735 Malibu Place
Escondido CA.92027(US)

(74) Representative: Liesegang, Roland, Dr.-Ing. et al
FORRESTER & BOEHMERT
Widenmayerstrasse 4
D-8000 München 22(DE)

(54) A process for producing successive droplets of ink of different sizes.

(57) The volume of a droplet (44) ejected from a thermal ink jet printer is controlled by the application of a low level of energy to an ink volume in an ink container (24) prior to application of a high energy pulse which vaporizes an ink bubble to eject ink from an orifice (26) of the print head. The energy is preferably applied to the ink by passing current through a resistor (30) in the wall of the ink container (24) in close proximity to the orifice (26). The initial low energy level or precursor signal warms, but does not vaporize, the ink adjacent the resistor (30) so that a larger volume of ink may be vaporized by the high energy pulse, increasing the ejected droplet size. Increasing the energy in the low energy heating increases the ejected droplet size. The low energy heating may be applied in various manners, such as a single long duration pulse, multiple short duration pulses, or the like. Variations in the energy of the precursor pulse for succeeding droplets cause corresponding variations in the sizes of the ejected droplets.

FIG. 1



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A PROCESS FOR PRODUCING SUCCESSIVE DROPLETS OF INK OF DIFFERENT SIZES

BACKGROUND OF THE INVENTION

This invention relates to thermal ink jet printers, and, more particularly, to the manner in which energy is introduced into the ink within the printer head to eject droplets.

Thermal ink jet print heads operate by rapidly heating a small volume of ink, causing it to vaporize and expand, thence ejecting a droplet of ink through an orifice to strike a printing medium such as a piece of paper. When a number of orifices are properly arranged, they form a dot matrix pattern. The properly sequenced operation of each orifice causes a pattern of characters or images to be printed upon the paper as the print head is moved past the paper. The thermal ink jet printer is fast but quiet, because only the ink strikes the paper, produces high quality characters and images, and can be made compact and portable.

In one design, the print head includes an ink reservoir and channels to supply the ink to the point of vaporization, an orifice plate in which the individual orifices are formed in the required pattern, a series of thin film heaters, one near each orifice, and a substrate which forms the back wall of the ink channel and upon which the heaters are supported. Each heater includes thin film resistors and appropriate current leads. To print a single dot of ink, electrical current from an external power supply is passed through a selected heater. The heater is ohmically heated, in turn heating the adjacent ink, vaporizing a small volume of the ink, and causing a droplet of ink to be ejected through the adjacent orifice to the paper as the vaporized volume expands.

An important characteristic of the print head is the size and volume of the droplet ejected. The larger the size of the droplet, the more intense the dot on the paper appears to the eye. A large dot also increases the amount of bleed between adjacent dots, impairing image quality. It would be desirable, therefore, to be able to actively control the volume of the droplet ejected to optimize the image intensity and quality in a variety of applications.

Several approaches have been proposed to control the size of the ink droplet ejected. Increasing the size of the ejection orifice permits formation of larger ejected droplets. Increasing the temperature of the print head increases the ejection pressure, and thence the size of the droplet. Increasing the resistor size increases the energy transmitted to the ink, and thence the droplet size. None of these approaches is operable, however, to achieve dynamic, essentially instantaneous control of the droplet size with a high degree of precision. Dynamic control is the ability to alter the size of individual droplets in a succession of droplets. An increased orifice size permits production of large droplets only. The temperature of the print head cannot be changed fast enough to effectively control droplet size in a series of droplets. Resistor size is essentially fixed in any one device.

Another approach has been proposed for controlling the droplet size. It is said that the size of the droplet can be changed by increasing the intensity or duration of the energy pulse. Although a small range of control may be possible with this approach, the vapor barrier created upon vaporization of the ink to form a bubble prevents effective control of droplet size by this technique. Erratic vapor bubble growth occurs, with the result that the individual droplets in a succession of droplets are observed to have uncontrollable and irregular variations in size.

There exists a need for a means for dynamically controlling the size of the droplet volume ejected from the print head. This approach should permit alteration of droplet volume over wide ranges, with the ability to change conditions quickly so as to produce different droplet volumes in a succession of rapidly produced droplets. The present invention fulfills this need, and further provides related advantages.

SUMMARY OF THE INVENTION

The present invention provides a process for controllably varying the size of individual droplets in a series ejected from a thermal ink jet printer head. By controlling droplet volume, the print intensity and quality can be optimized. This approach permits the printing of improved half-tone black-and-white images and improved color images. The quality of the images can also be readily altered to adjust for particular types of inks and print media. The process of the invention can be practiced without changing the print head hardware of the thermal ink jet printer, and requires at most only a change in the electronics of the power supply.

In accordance with the invention, a process for producing successive droplets of ink of different sizes comprises the steps of supplying a thermal ink jet drop ejector including a container holding a volume of ink, an orifice in one wall of the container, an electrical resistance heater in a wall of the container in proximity to the orifice, and a

power supply connected to the electrical resistance heater; applying a first electrical precursor signal to the resistance heater from the power supply to preheat the ink adjacent the resistance heater, the precursor signal having insufficient energy to cause vaporization of the ink in the container; applying a first electrical ejector signal to the resistance heater from the power supply to eject a droplet of ink, the ejector signal having sufficient energy to vaporize ink adjacent the resistance heater, the ejector signal being applied while the ink adjacent the resistance heater is still heated from application of the precursor signal; applying a second electrical precursor signal to the resistance heater from the power supply to preheat the ink adjacent the resistance heater, the precursor signal having insufficient energy to cause vaporization of the ink in the container, the second electrical precursor signal being different from the first electrical precursor signal; and applying a second electrical ejector signal to the resistance heater from the power supply to eject a droplet of ink, the ejector signal having sufficient energy to vaporize ink adjacent the resistance heater, the ejector signal being applied while the ink adjacent the resistance heater is still heated from application of the precursor signal.

The resistance heater is a heat source, and the invention may be more generally described in terms of introduction of heat into the ink. In accordance with this concept, a process for producing successive droplets of ink of different sizes comprises the steps of supplying a thermal ink jet drop ejector including a container holding a volume of ink, an orifice in one wall of the container, and a heat source in the container; ejecting a first droplet of ink by heating the ink with the heat source operated under two different conditions of heat production, a first condition of heat production wherein the heat output of the heat source is less than that required to vaporize any ink, and thereafter a second condition of heat production wherein the heat output of the heat source is greater than that required to vaporize a volume of the ink, thereby ejecting a first droplet of ink through the orifice; and ejecting a second droplet of ink by heating the ink with the heat source operated under two different conditions of heat production, a first condition of heat production wherein the heat output of the heat source is less than that required to vaporize any ink, and the heating of the ink is different from the heating of the ink during the first condition of heat production in the step of ejecting a first droplet of ink, and thereafter a second condition of heat production wherein the heat output of the heat source is gr ater than that required to vaporize a volume of the ink, thereby ejecting a second droplet of ink through the orifice. As used herein, the "conditions" of heat production are th combination of circumstances under which heat is produced, including the heating rate, duration of heating, number and type of heating events, and delay between heating events, and any other relevant considerations.

The invention may also be thought of in terms of heating the ink to different temperatures in the successive precursor steps. In accordance with this aspect of the invention, a process for producing successive droplets of ink of different sizes comprises the steps of supplying a thermal ink jet drop ejector including a container holding a volume of ink, an orifice in one wall of the container, and means for heating the ink; ejecting a first droplet of ink by heating the ink,with the means for heating to a first temperature insufficient to nucleate a vapor bubble in the ink; and thereafter heating the ink with the means for heating to a second temperature sufficient to nucleate a vapor bubble in the ink and drive a droplet of ink through the orifice, the heating to the second temperature to occur at a time sufficiently shortly after the heating to the first temperature that the ink has not cooled to its initial temperature; ejecting a second droplet of ink by heating the ink with the means for heating to a first temperature insufficient to nucleate a vapor bubble in the ink, the first temperature in the step of ejecting a second droplet being different from the first temperature in the step of ejecting a first droplet; and thereafter heating the ink with the means for heating to a second temperature sufficient to nucleate a vapor bubble in the ink and drive a droplet of ink through the orifice, the heating to the second temperature to occur at a time sufficiently shortly after the heating to the first temperature that the ink has not cooled to its initial temperature.

The present invention provides for controlling the ejected droplet size by first heating the ink with a low level of introduced energy, and then vaporizing a volume of ink to eject a droplet with a high level of introduced energy. The initial low level of applied energy is conveniently discussed as a precursor signal or pulse, and the subsequent high level of applied energy is conveniently discussed as an ejector signal or pulse. The term "pulse", as used herein, means a single pulse or a succession of pulses coordinated to achieve the desired low or high level of introduced energy.

The precursor pulse heats the ink adjacent the heat source, but does not cause vaporization of the ink. The temperature of a volume of ink near the heat source is raised, but not to the vaporization temperature. The duration of the precursor pulse is on the order of microseconds, and the time between completion of the precursor pulse and the initiation of the ejection puls ranges from zero to microseconds. The volume of the ink whose tem-

perature is raised by the precursor pulse is therefore small, because the heat from the source cannot diffuse a great distance into the ink prior to the initiation of the ejector pulse. Nevertheless, the raising of the temperature of that small volume of ink, with the precursor pulse, permits the ejector pulse to vaporize a greater volume of ink, which in turn provides a greater expansive force that ejects a greater volume of ink. The volume of successive ejected droplets is controlled by altering the amount of energy introduced into the ink during the precursor pulse.

The precursor pulse and the ejector pulse are distinguishable in that the precursor pulse introduces energy into the ink at a rate insufficient to cause vaporization, while the ejector pulse introduces energy into the ink at a rate sufficient to cause vaporization. Within this constraint, the precursor pulse can have a wide variety of forms. The precursor pulse can be a single sustained pulse, or multiple pulses, that terminate prior to initiation of the ejector pulse. The precursor pulse can also be a single sustained pulse that does not terminate prior to the initiation of the ejector pulse, but is continuous with the ejector pulse. The precursor pulse can be multiple distinct pulses, the last of which is continuous with the ejector pulse.

The present approach is thus distinguished from simply changing the energy level or duration of a single ejector pulse. Decreasing the energy or duration of the single ejector pulse below a minimal level eventually results in an inability to eject a droplet. Increasing the energy or duration of the single ejector pulse above that required to eject a droplet has very little effect on drop volume, because the ink vaporized acts as an effective thermal diffusion barrier to the introduction of more energy that would vaporize a greater volume of ink. The additional energy is directed downwardly into the substrate, resulting in undesirable side effects, rather than into the ink.

The present approach is also distinguishable from the approaches of changing the resistor size, orifice size and the print head temperature. Although conceptually any or all of these factors may be changed, they may not be changed rapidly enough to permit control of the volume of a succession of droplets that are ejected tens of milliseconds apart.

The present invention tailors the energy used to form each droplet to that appropriate to a selected size, so that the volume of each ink droplet may be selected. Since each ejection sequence removes the heated ink from the container, the character of a droplet is not influenced by that of prior or subsequent droplets, nor does it influence prior or subsequent droplets, once an quilibrium operating temperature is reached.

The volume of the ejected droplet can be varied over at least about 40 percent by controlling the character of the precursor pulse, which has been shown to be sufficient for many applications in optimization of quality and appearance of the image. Increasing the volume of each droplet increases the intensity of the resulting ink dot on the print medium, so that regions of the image can be made to appear darker without changing the number of dots per unit area. The volume control of the present invention also permits the character of the dot to be adjusted for the nature of the print medium. For example, some papers are more porous than others, so that large dots tend to bleed into adjacent dots. The sharpness of the image can be improved by reducing the drop volume for such media.

The present invention has important advantages in color printing. Intermediate colors can be produced by the drop-on-drop (DOD) technique, wherein dots of different primary colors are overprinted to produce an intermediate color. Control of the drop volume permits improved precision in the selection of the intermediate color, as well as prevention of bleeding of one color into another.

Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a side elevational view of a portion of a print head for a thermal ink jet printer;

Figure 2 is a pictorial circuit diagram for the thermal ink jet printer;

Figure 3 is a graph of voltage versus time for a first combination of precursor and ejector pulses;

Figure 4 is a graph of voltage versus time for a second combination of precursor and ejector pulses;

Figure 5 is a graph of voltage versus time for a third combination of precursor and ejector pulses;

Figure 6 is a graph of droplet volume versus voltage for the combination of Figure 3;

Figure 7 is a graph of droplet volume versus delay time for the combination of Figure 5; and

Figure 8 is an enlargement of a matrix of dots of ink deposited upon a sheet of paper, produced without a precursor pulse; and

Figure 9 is an enlargement of a matrix of dots of ink deposited upon a sheet of paper, produced with a precursor puls .

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A portion of a preferred thermal ink jet printer head is presented in Figure 1, showing the relation of the major components. Referring to Figure 1, a thermal ink jet printer head 20 includes an orifice plate 22 having an ink container 24 therein. The ink container 24 is in the form of a channel elongated perpendicular to the plane of the illustration. The orifice plate 22 has a number of orifices, including the illustrated orifice 26. Ink is drawn from a reservoir (not shown) to the region of the orifice 26 and the ink container 24, by capillary action.

Opposite the opening of the orifice 26 is a heater 28. The heater 28 is a thin film resistor including a tantalum-aluminum planar resistor element 30 and aluminum or gold leads 32 connecting to the resistor element 30. A voltage is applied to the leads 32, which causes a current to flow through the portion of the resistor element 30 between the ends of the leads 32, rapidly heating the resistor element 30. A small volume of ink adjacent the heater 28 is thereby heated. A passivation layer 34 overlies the heater 28, to protect it from corrosion by the ink. The passivation layer 34 typically includes a silicon carbide layer 36 immediately overlying the heater 28, and a tantalum layer 38 overlying the silicon carbide layer 36. The heater 28 is supported on a substrate 39, which includes a silicon or glass base 40, with an overlying layer of silicon dioxide 42.

By way of illustration of the types of materials and dimensions of the printer head 20 and not by way of limitation, in a preferred printer head 20 the base 40 is a polycrystalline silicon wafer about 500 micrometers thick, and the silicon dioxide layer 42 is about 1.7 micrometers thick. The resistor element 30 is an alloy of tantalum and aluminum containing about 40 percent by weight aluminum. The resistor element 30 is about 50 micrometers long, about 50 micrometers wide, and about 0.6 micrometers thick. The leads 32 are aluminum and about 0.5 micrometers thick. The silicon carbide layer 36 is about 0.75 micrometers thick, and the tantalum layer 38 is about 0.6 micrometers thick. The orifice plate 22 is electroformed nickel, with the diameter of the orifice 26 being from about 10 to about 60 micrometers in diameter. The present invention is operable with such a preferred printer head 20, and with other printer heads that operate in a similar fashion, such as printer heads wherein the droplet is ejected from a tubular structure and the heater is separated from the point of ejection.

A voltage is applied between the leads 32, which in turn causes a current to pass through the resistor element 30 to heat the heater 28 by ohmic heating. Figure 2 depicts the circuit for providing a voltage across the leads 32. One of the leads 32 is grounded to the frame of the printer, and the other is connected to a power supply 50 having the necessary voltage and current capacity to supply the energy required. The signal output of the power supply 50 is controlled by a digital or analog function generator 52. A digital function generator is preferred, as it can be readily programmed with particular waveforms. In a general form, a microprocessor 54 controls the function generator 52 to select particular waveforms. The waveforms produced by the function generator 52 are translated into the applied voltages in the power supply 50, and supplied to the leads 32.

Figures 3-5 illustrate three sets of operable precursor and ejector pulse forms. In each case, an ejector pulse 60 is a square wave, with a rapidly rising leading edge. The energy produced when the ejector pulse 60 passes through the resistor element is sufficient to vaporize a volume of ink in the container 24 adjacent the resistor element 30. The vaporized volume of ink expands, forcing a droplet 44 of ink out of the orifice 26 to impact against a print medium 46. For a typical printer head 20 as described above, the voltage of the ejector pulse 60 is about 15 volts, and the duration of the pulse is from about 2 to about 4 microseconds.

Three types of precursor pulses 62 are illustrated in Figures 3-5, respectively, as exemplary of the types of pulses that are operable. The illustrated precursor pulses 62 are preferred, but any other type of pulse structure is acceptable as long as it does not cause vaporization of the ink adjacent the resistor element 30.

The precursor pulse 62 of Figure 3 is a continuous pulse of low voltage, which is contiguous in time with the initiation of the leading edge of the ejector pulse 60. For a typical printer head 20 as described above, the voltage of the precursor pulse 62 is about 4 volts, and its duration is from about 1 to about 80 microseconds. Both the voltage and the duration can be varied, as long as the energy transfer into the ink adjacent the resistor element 30 is not sufficiently rapid to cause vaporization or boiling of the ink by raising its temperature to the vaporization temperature.

Two sets of pulses are illustrated in Figure 3, each having a precursor pulse 62 and an ejector pulse 60. The first precursor pulse 62 is longer than the second precursor pulse 62′, so that more energy is introduced into the ink and the ink is raised to a different temperature by the first precursor pulse 62. The droplet ejected by the first ejector pulse 60 will therefore be of a different (greater) size that that ejected by the second ejector pulse 60′.

The precursor pulse 62 of Figure 4 is a discontinuous pulse of higher voltage, comprising three individual subpulses 64. For a typical printer head 20 as described above, the voltage of each of the three precursor subpulses 64 is about 12 volts, the same as the voltage of the ejector pulse 60, each subpulse 64 has a duration of about 1-2 microseconds, and the separation time between the end of the last subpulse 64 and the initiation of the ejector pulse 60 is about 3-6 microseconds. The second group of precursor pulses 62′ is similar to the group of pulses 62, as is the second ejector pulse 60′ similar to the first ejector pulse 60. The difference between the set of pulses 60, 62 and the set 60′, 62′ is the delay time t_{delay} between the precursor pulses and the ejector pulse. The t_{delay} between the pulses 62 and 60 is less than the t'_{delay} between the pulses 62′ and 60′, and the ink has longer to cool between the pulses 62′ and 60′. The droplet second droplet ejected therefore is smaller than the first droplet ejected.

The precursor pulse 62 of Figure 5 is similar to that of Figure 4, but involves only a single subpulse 66. In the illustrated form, the voltage of the precursor pulse 62 is the same as the voltage of the ejector pulse 60, and the duration of each of the pulses 60 and 62 is constant. As will be seen, the volume of the ejected droplet is controlled by the delay time t_{delay} between the end of the precursor pulse and the initiation of the ejector pulse.

Each of the approaches illustrated in Figures 3-5 has particular advantages. The precursor pulse 62 of Figure 3 is readily generated by inexpensive function generators, and is controllable through manipulation of two variables, the voltage and duration of the precursor pulse 62. The precursor pulse 62 of Figure 4 provides greater flexibility due to the greater number of controllable variables. The precursor pulse 62 of Figure 5 is simple, and permits control of drop volume by manipulation of a single variable, t_{delay}. At the present time, the less complex approach of Figure 3 has been found to produce a linear, readily predictable relationship between drop volume and precursor energy, and is the most preferred embodiment of the invention.

The different waveforms of Figures 3-5 are illustrative of the flexibility of the approach of the invention to selecting a variety of waveforms. Whatever its precise form, the precursor pulse may not be such that it causes vaporization of the ink adjacent the resistor element 30. Such vaporization would create a vapor barrier between the resistor and the remainder of the ink volume, causing erratic vaporization and irregular droplets. Within that constraint, any suitable waveform and combination of parameters may be utilized.

Figures 6 and 7 show th effects of adjusting operating variables of the precursor pulses utilized in Figures 3 and 5, respectively. In each case, the preferred print head 20 described earlier was utilized, with an ejector pulse in the form of a square wave of about 12 volts and duration about 4 microseconds, and the droplet volume produced by the print head was measured.

Figure 6 illustrates the volume of the droplet (normalized relative to the volume of the droplet when no precursor pulse is applied) as a function of the duration of the applied precursor pulse 62 in the waveform of Figure 3, with a constant voltage of the precursor pulse 62 of about 3-4 volts. The volume of the droplet increases approximately linearly with increasing duration of the precursor pulse 62.

Figure 7 illustrates the volume of the droplet (normalized relative to the volume of the droplet when no precursor pulse is applied) as a function of the separation time t_{delay} between the end of the subpulse 66 of Figure 5, and the initiation of the ejector pulse 60. The voltage of the subpulse 66 was the same as the voltage of the ejector pulse 60, about 12-13 volts, the duration of the subpulse 66 was 1 microsecond, and the separation t_{delay} between the subpulse 66 and the ejector pulse 60 was variable. The droplet volume first increases with increasing t_{delay}, as the thermal pulse of the precursor subpulse 66 spreads outwardly from the resistor element 30, reaches a maximum, and then decreases as the pulses 66 and 60 become so far apart that the benefits of the precursor heating are lost by thermal diffusion. The optimum separation for maximum droplet increase (the maximum point of the curve of Figure 7) is about 3-6 microseconds, for this particular geometry and waveform configuration.

The shape of Figure 7 demonstrates the ability to control the droplet size and volume accurately by controlling the separation time, particularly on the negatively sloped portion of the curve (in this case that portion above about 4 microseconds). On this slowly varying portion of the curve, increasing the separation time slowly decreases the droplet size and volume, between the limits of the maximum size and the size produced by the unaided ejector pulse.

Figures 8 and 9 illustrate the effect of changing the droplet volume on the image produced by the impact of the droplet on the print medium. The dots of Figures 8 and 9 are equally enlarged reproductions of a series of actual dot images. The dot image of Figure 8 was produced by an unaided ejector pulse 60 (that is, with no precursor pulse). The dot image of Figure 9 was produced by a droplet that was about 20 percent larger than the droplet producing the dot image of Figure 8, under conditions at the maximum point of 4 microseconds separation time illustrated in Figure 7.

The present approach permits dynamic control of the droplet volume, and hence printed dot size, of an inkjet printer. Control is achieved by varying precursor heating, and is readily accomplished using existing print heads in conjunction with properly controlled function generators. Although a particular embodiment of the invention has been described in detail for purposes of illustration, various modifications may be made without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited except as by the appended claims.

Claims

1. A process for producing successive droplets of ink of different sizes, comprising the steps of supplying a thermal ink jet drop ejector including a container (24) holding a volume of ink, an orifice (26) in one wall (22) of the container, and a heat source (30) for heating the ink, **characterized** by ejecting a first droplet of ink by heating the ink with the heat source (30) operated under two different conditions of heat production, a first condition of heat production wherein the heat output of the heat source is less than that required to vaporize any ink, and thereafter a second condition of heat production wherein the heat output of the heat source is greater than that required to vaporize a volume of the ink, thereby ejecting a first droplet of ink through the orifice; and
ejecting a second droplet of ink by heating the ink with the heat source operated under two different conditions of heat production, a first condition of heat production wherein the heat output of the heat source is less than that required to vaporize any ink, and the heating of the ink is different from the heating of the ink during the first condition of heat production in the step of ejecting a first droplet of ink, and thereafter
a second condition of heat production wherein the heat output of the heat source is greater than that required to vaporize a volume of the ink, thereby ejecting a second droplet of ink through the orifice (26).

2. The process of claim 1, **characterized** in that the time duration of heating ink during the first condition of heat production in the step of ejecting a second droplet is greater than the time duration of heating ink during the first condition of heat production in the step of ejecting a first droplet.

3 The process of claim 1 or 2, **characterized** in that the rate of introducing heat into the ink during the first condition of heat production portion of the step of ej cting a second droplet is greater than the rate of introducing heat into the ink during the first condition of heat production portion of the step of ejecting a first droplet.

4. The process of one of claims 1 to 3, **characterized** in that the total heat introduced into the ink under the first condition of heat production portion of the step of ejecting a second droplet is greater than the total heat introduced into the ink under the first condition of heat production portion of the step of ejecting a first droplet.

5. The process of one of claims 1 to 4, **characterized** in that the first condition of heat production portion of the step of ejecting a first droplet involves a single pulse of heat.

6. The process of claim 5, **characterized** in that the single pulse is continuous with a pulse of heating in the second condition of heat production of the step of ejecting a first droplet.

7. The process of one of claims 1 to 6, **characterized** in that the second condition of heat production in the step of ejecting a first droplet is the same as the second condition of heat production in the step of ejecting a second droplet.

8. A process according to the precharacterizing part of claim 1, **characterized** in that for ejecting a first droplet of ink the ink is heated to a first temperature insufficient to nucleate a vapor bubble in the ink: and thereafter the ink is heated to a second temperature sufficient to nucleate a vapor bubble in the ink and drive a droplet of ink through the orifice, the heating to the second temperature to occur at a time sufficiently shortly after the heating to the first temperature that the ink has not cooled to its initial temperature; and for ejecting a second droplet of ink the ink is heated to a first temperature insufficient to nucleate a vapor bubble in the ink, the first temperature in the step of ejecting a second droplet being different from the first temperature in the step of ejecting a first droplet; and thereafter the ink is heated to a second temperature sufficient to nucleate a vapor bubble in the ink and drive a droplet of ink through the orifice, the heating to the second temperature to occur at a time sufficiently shortly after the heating to the first temperature that the ink has not cooled to its initial temperature.

9. A process according to the precharacterizing part of claim 1, **characterized** by
ejecting a first droplet of ink by heating the ink with the heat source operating at a heat output greater than that required to vaporize a volume of the ink; and
ejecting a second droplet of ink by heating the ink with the heat source operated under two different conditions of heat production, a first condition of heat production wherein the heat output of the heat source is less than that required to vaporize any ink; and thereafter a second condition of heat production wherein the heat output of the heat source is greater than that required to vaporize a volume

of the ink, thereby ejecting a second droplet of ink through the orifice.

10.The process of claim 9, including the additional step, after the step of supplying and before the step of ejecting a first droplet, of heating the ink with the heat source operated so that the heat output is less than that required to vaporize any ink.

11.The process of one of claims 1 to 10, **characterzed** in that the heat source is an electrical resistance heater (30) located in the wall (38) of the container (24).

12.A process according to one of claims 1 to 10, characterized in that the heat source is an electrical resistance heater (28) located in the wall of the container in proximity to the orifice (26),
that a power supply (50) is connected to the electrical resistance heater (30), that a first electrical precursor signal (62) is applied to the resistance heater (30) from the power supply (50) to preheat the ink adjacent the resistance heater, the precursor signal having insufficient energy to cause vaporization of the ink in the container,
applying a first electrical ejector signal (60) to the resistance heater (30) from the power supply (50) to eject a droplet of ink, the ejector signal having sufficient energy to vaporize ink adjacent the resistance heater, the ejector signal being applied while the ink adjacent the resistance heater is still heated from application of the precursor signal;
applying a second electrical precursor signal (62′) to the resistance heater from the power supply to preheat the ink adjacent the resistance heater, the precursor signal having insufficient energy to cause vaporization of the ink in the container, the second electrical precursor signal being different from the first electrical precursor signal, and
applying a second electrical ejector signal (60′) to the resistance heater from the power supply to eject a droplet of ink, the ejector signal having sufficient energy to vaporize ink adjacent the resistance heater, the ejector signal being applied while the ink adjacent the resistance heater is still heated from application of the precursor signal.

13.The process of claim 12, **characterized** in that each precursor signal (62,62′) is applied as a single pulse, and each ejector signal (60,60′) is applied immediately upon completion of the precursor signal (Fig. 3).

14.The process of claim 12, **characterized** in that each precursor signal (62,62′) is applied as a succession of pulses (64) (Fig. 4).

15.The process of claim 12 or 14, **characterized** in that each ejector signal (60,60′) is applied as a single pulse having a square leading edge (Fig. 4,5):

FIG. 1

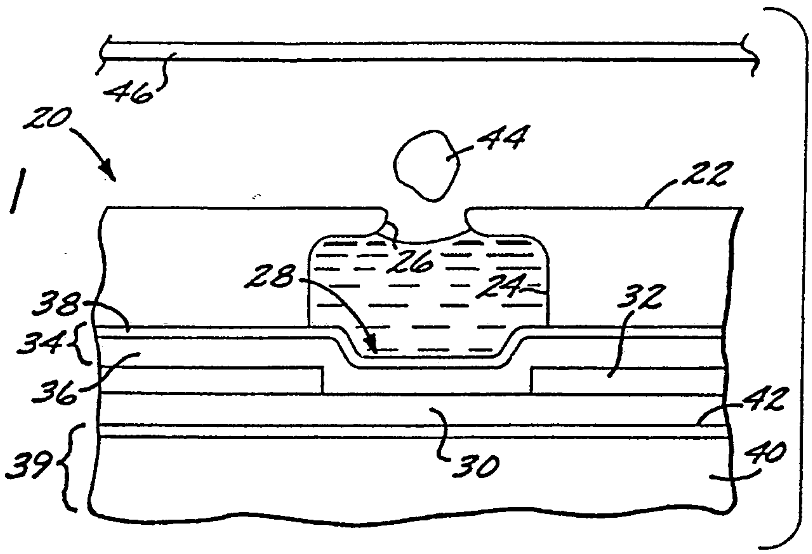


FIG. 2

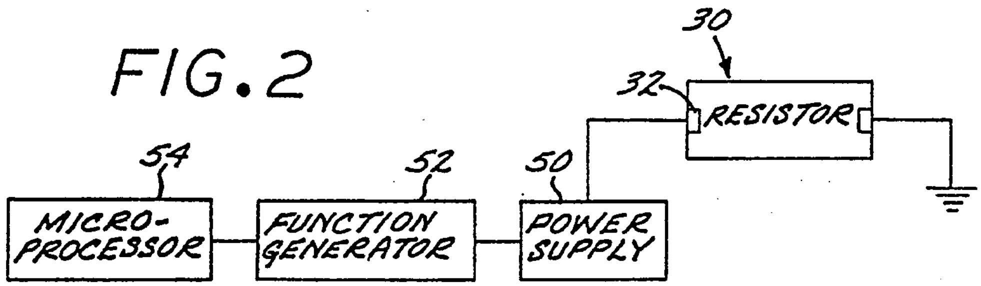


FIG. 3

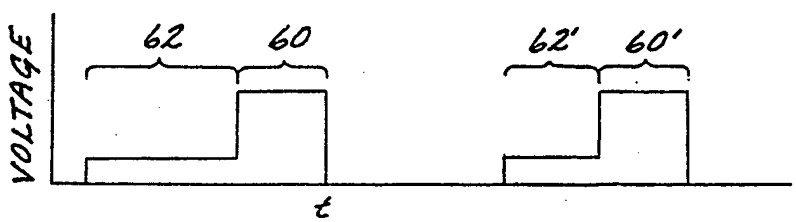


FIG. 4

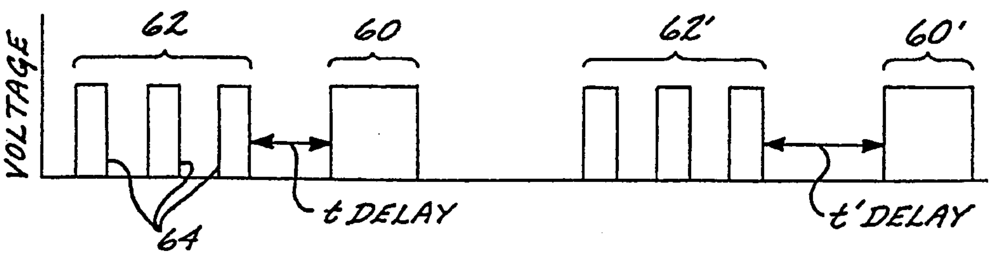


FIG.5

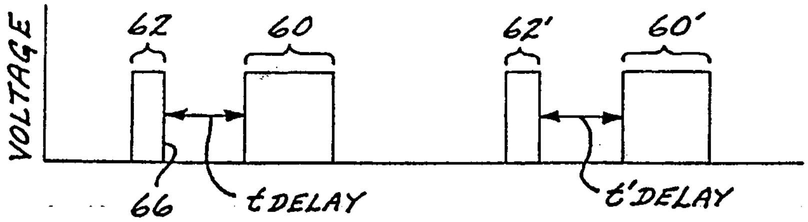


FIG.6

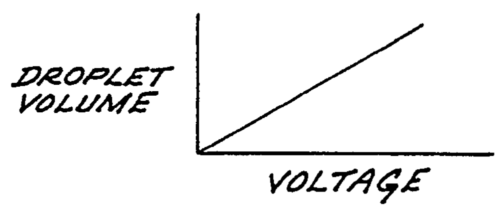


FIG.7

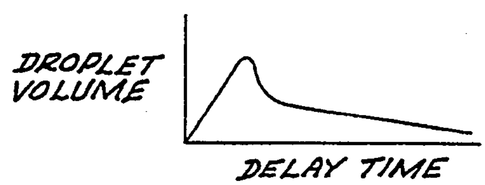


FIG.8

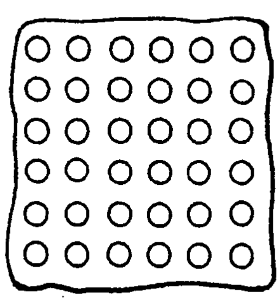
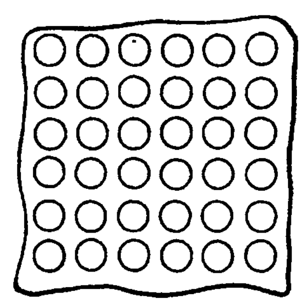


FIG.9



European Patent Offic

EUROPEAN SEARCH REPORT

Application number

EP 89107684.6

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	GB - A - 2 106 039 (HEWLETT PACKARD) * Page 3, line 101 - page 4, line 12 *	1,5,6, 8-13, 15	B 41 J 3/04
A	EP - A2 - 0 205 243 (OLIVETTI) * Claim 1 *	1,5,8-10,12	
A	EP - A2 - 0 194 852 (EXXON PRINTING SYSTEMS)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 41 J G 01 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	10-10-1989	WITTMANN

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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